ECOLOGY

Project title: Cross-Boundary Plant Invasions in Protected Areas: The West Yellowstone Area

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Additional investigator(s): Anibal Pauchard

Objective: To 1) determine susceptibility of plant communities to invasion at the landscape scale in the interface between Gallatin NF and Yellowstone NP; 2) determine both forest edge effects on alien plant invasions and biodiversity patterns, contrasting natural and human disturbances; and 3) determine the invasive strategy of *Linaria vulgaris Mill.* at multiple spatial scales in the study area and characterize its potential to invade areas in relation with disturbance types and regimes.

Findings: Our results show that invasions are widely spread across the study area, but are much more prominent in the Gallatin NF. In Yellowstone NP, invasive species occupy disturbed areas along roads and seem to be expanding to more pristine areas such as riparian corridors and naturally disturbed areas. We found significant differences in community patterns in relation to disturbance types. Road edges have the higher numbers of exotic species, followed by clearcut edges. Fire edges have a low number of exotic species. In general, invasive species do not penetrate forest edges. Based on our preliminary results, we conclude that *L. vulgaris* is primarily colonizing old clearcuts and other areas with a disturbed soil layer. *L. vulgaris* patches do not seem to be dying back and their overall population is increasing. We conclude from this preliminary analysis that invasive species in the study area respond both to landscape mechanisms of dispersal along corridors across patch mosaics and site level disturbance factors. While *L. vulgaris* is generally not considered a major species of concern in the northern Rockies regionally, in the unique climatic and geological setting of GYA our data suggests common toadflax has the potential to become a significant problem both inside and outside the park. We will collect more data in the field during the summer 2001 and will conduct other statistical analysis to complete our research project.

Project title: Relating Avian Abundance and Diversity to Human Disturbance Regimes via Hyperspectral Imaging

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Objective: To 1) identify areas of significant avian abundance diversity within riparian zones on the northern range; 2) identify areas supporting amphibian breeding, foraging, and dispersal activities within riparian zones on the northern range; 3) relate hyperspectral imaging data to patterns of habitat, avian, and herptile abundances and distribution; and 4) relate diversity and abundance patterns to anthropogenic disturbance regimes within and between drainages.

Findings: During our first year of field investigations we sampled 228 point count plots for birds, yielding 3,134 individuals comprising 95 species. The most numerous passerines detected within 100m on point counts were Cliff Swallows *(Petrochelidonpyrrhonata)* owing to their gregarious nature, American Robins *(Turdus migratorius),* and Savannah Sparrows *(Passerculus sandwichensis).* Savannah Sparrows were found in sedge- *(Carex sp.)* dominated areas, whereas at the other end of the vegetation gradient, Lincoln's Sparrows *(Melospiza lincolnii)* were consistently found in willow *(Salix spp.)* stands. Thus far, we have identified significant drainage effects upon levels of riparian bird community diversity and abundance. Bird abundance, species richness, and diversity were positively related to willow abundance but showed varying patterns between drainages on the northern range. We are refining measures to more accurately describe species replacements associated with habitat features such as basin characteristics, floodplain size, and riparian shrub height and density. Development of an Index of Biotic Integrity relating specifically to shrub-dependent passerines is ongoing, and assessment of these measures will be done in cooperation with other Yellowstone Ecosystem Studies projects, especially the Hyperspectral Imaging Research. Moreover, these metrics will become environmental parameters for herpetelogical work. These same drainages have been surveyed for amphibians and reptiles identifying one previously unknown boreal toad *(Bufo boreas)* breeding site as well as breeding sites of Columbia spotted frogs *(Rana lutieventris)* and boreal chorus frogs *(Pseudacris maculata).*

Project title: The Ecological Relationship Between a Rocky Mountain Threatened Species and a Great Plains Agricultural Pest

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Additional investigator(s): Hillary Robison

Objective: 1) To determine where army cutworm moths *(Euxoa auxiliaris)* (ACMs) originate using microsatellite and mtDNA markers. Pressures on ACM subpopulations, either natural (e.g., weather patterns) or human-caused (e.g., pesticides or habitat loss), may affect moth recruitment and the numbers of adults reaching high elevation sites where they are a critical food source for the threatened grizzly bear

(Ursus arctos horribilis). 2) To determine if ACMs harbor agricultural pesticides in their tissues. Resulting magnification in grizzly bears that forage heavily on moths may have detrimental physiological or developmental side effects. 3) To determine whether ACMs from different Great Plains origins are interbreeding in high elevation sites prior to their return to agricultural areas. If ACM subpopulations do not interbreed, unfavorable conditions in specific Great Plains areas may impact moth numbers in high elevation.

Findings: This project is ongoing.

Project title: Effects of Fires on Ecology of Coyotes in Yellowstone National Park: Baseline Succeeding Wolf Recovery

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Additional investigator(s): Jennifer Sheldon, David Bopp, Paul Moorcroft, Chris Wilmers

Objective: Document long-term effects of the 1988 fires on the population dynamics and behavioral ecology of coyotes. Document the impacts of wolf restoration on coyote population and behavioral ecology including effects of coyote prey and competitor species. Continue long-term monitoring of coyote populations by adhering to those objectives listed in previous reports and peer-reviewed publications.

Findings: This project is beginning year twelve and is in Phase II: Wolf colonization period. A variety of significant behavioral and demographic effects of wolves on coyotes continue to occur since the release of wolves in 1995. The direct effects of fires on coyotes continue to be insignificant, but indirect effects on the small mammal prey base continue. Currently (2001), thirty-five resident adult coyotes occupy the Lamar Valley study area, and 20 occupy the Blacktail Plateau study area. In the year 2000, the Druid wolf pack expanded its range to include what was formerly a buffer zone between two neighboring wolf packs, and the coyote population in this zone, formerly stable, was reduced by 50 percent, with a concomitant acceleration of alpha pair turnover. Due to the lack of consumable biomass after the larger wolf packs finish their first feeding, coyote use of wolf-killed carcasses has decreased markedly in 2000.

Project title: Landscape Use by Elk During Winter on Yellowstone's Northern Range

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Objective: The objectives of this study were to document winter patterns of landscape use by Yellowstone northern range elk; measure elk feeding activity (as indexed by number of feeding craters); quantify snowpack characteristics; and examine how these and other landscape and habitat features influence elk foraging locations. How does snow affect the distribution of elk during winter on Yellowstone's northern range? What other factors, such as winter temperature, forage, and predator/prey density, are affecting their distribution?

Findings: We measured site and snowpack characteristics, elk *(Cervus elaphus)* feeding crater densities and morphometry, and elk numbers in the Lamar River Valley and the Blacktail Plateau on the northern range of Yellowstone National Park, Wyoming. We conducted the study over three winters, 1992-93 to 1994-95, but the main sampling effort occurred over four monthly sample periods in year one. Snow depth (SD), snow water equivalent (SWE) and snow resistance to horizontal movement and vertical penetration all increased steadily over the winter. The mean (SD) feeding crater diameter and depth was 118 (37) cm and 34 (11) cm, respectively, and both were positively correlated with snow depth. The mean (SD) crater volume was 385 (321) l, and the mean (SD) mass of snow excavated from a crater was 82 (72) kg. Nonwoody plants (grasses, sedges and forbs) were the primary browse item in 90 percent of the craters. The highest aerial elk counts were observed in early- to mid-January, and counts declined substantially and steadily after January 29. At this time, mean snow depth was about 50 cm and mean SWE was about 12 cm. The mean number of new craters on a plot showed a significant, negative association with snow depth, SWE and booted-foot sinking depth. We used the sum of craters on a plot across all four sample periods as an index of winter-long feeding activity. Elevation and habitat type were the best site characteristics for differentiating plots in regard to winter-long use. Summed craters were negatively associated with elevation, and the habitat type with the highest summed craters was tufted hairgrass/sedge. Only about 5 percent of plots that had craters had areal crater coverage in excess of 14 percent, with a maximum of 23 percent coverage, suggesting that snow disturbance associated with cratering activity may inhibit elk foraging. We are preparing manuscripts for publication and are also preparing for field work starting November 2001.

Project title: Specificity in Ectomycorrhizal Symbioses

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Objective: To determine patterns of plant/ectomycorrhizal fungal interaction in multiple forest types, and determine effects of disturbance on these systems.

Findings: 1) no support for specificity; 2) clear patterns of seasonal variation; 3) significant effects of defoliation of pine on mycorrhizae of both pine and spruce; 4) significant effects of litter addition on mycorrhizal community structure in pure pine; 5) significant effects of litter removal on mycorrhizal community structure in mixed pine/spruce; and 6) significant differences between effects of clear-cutting and natural

burn in pure lodgepole pine.

Project title: Molecular Assessment of Microbial Communities in Hot Spring Structures and Their Responses to Light Manipulation

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Additional investigator(s): Dr. Evan Lau

Objective: To 1) determine patterns of evolution of cyanobacteria forming stromatolites in lithifying mats in hot springs; 2) determine effects of light and temperature gradients on these communities; and 3) Determine if stromatolite morphology is related to cyanobacterial community structure in mats.

Findings: Sampling along thermal gradients has been completed, as has sampling of mat vs. stromatolite and of different stromatolite morphs. DNA analysis is underway. Initial results indicate that cyanobacteria forming these modern stromatolites, that are analogs to 3.5 billion year old fossils, have a single phylogenetic origin.

Project title: Habitat Requirements and Evolution of *Agrostis rossiae Vasey,* a Grass Endemic to Thermal Soils in Yellowstone National Park

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Objective: To 1) use genetic markers to determine the phylogenetic relationship between *Agrostis rossiae* and closely related congeners, determine whether *A. rossiae* is a valid, monophyletic taxon or an ecotype of other co-occuring *Agrostis* species; 2) explain the geographic distribution of *A. rossiae* in terms of ecological variables; determine the reasons for its endemism; and 3) Calculate levels of gene flow between *A. rossiae* populations and between *A. rossiae* and co-occurring congeners.

Findings: 1) Genetics samples of 10 *Agrostis* species and over 20 *A. rossiae* populations were collected dur-

ing Spring/Summer 2000. RAPDS primer screening has been completed and data collection is underway. 2) Field measurements of soil temperature, moisture, and chemical composition have prompted greenhouse experiments, which are currently underway. Cross-pollination and self-pollination experiments are also being conducted. 3) Common garden experiments show that *A. rossiae* retains its distinct morphology under a wide variety of growing conditions.

Project title: Browsing Phenolgy of Willows, Cottonwood and Aspen on the Northern Range, Yellowstone National Park

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Additional investigator(s): YES personnel as assigned

Objective: The purpose of this project is to document variation in the timing of winter browsing of woody riparian species and relate it to climatic conditions.

Findings: During the first winter it appears that little browsing occurred until late January/early February, then most of the stems were eaten. One stand was not touched and several inches of last summer's growth were left on most stands. At one site it was noted that many branches were bitten off and left on the ground. It was also decided that a slight change in the observation protocol would provide more information. An estimate of percentage of twigs browsed will be recorded for each of 5 to 10 subplots at each site using the common 6 class system of less than 5 percent, 5-25 percent , 25-50 percent, 50-75 percent, 75-95 percent, greater than 95 percent. This method will be evaluated this winter.

Project title: Assessing Ecosystem Integrity: An Approach to Modeling Energy Flow

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Objective: To determine secondary invertebrate production in wetlands of the Lamar Valley and develop methods for modeling production.

Findings: In 2000, field studies were limited to one visit. During this visit data were collected on respira-

tion rates of six species of aquatic invertebrates inhabiting wetlands. These data will be used in modeling the energetics of these species.

Project title: The Sustainability of Grazing Ecosystems

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Objective: To measure the effects of grazing ungulates on aboveground and belowground production at diverse grassland sites on winter, transitional, and summer ranges.

Findings: 1) In 1999, grazers increased both shoot and root production. 2) Ungulates increased the fine grain spatial heterogeneity of soil N content and N mineralization. c In a growth chamber study, defoliating a common Yellowstone grass, Poa pratensis, increased root carbon exudation, rhizospheric microbial biomass, microbial activity, and N mineralization. These effects in the rhizosphere were associated with increased N uptake, plant N content, and photosynthetic rates in clipped plants.

Project title: Yellowstone Science and Technology Trip

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Objective: The goal of this experience is to put students into a natural setting that will stimulate their curiosity and excitement. Yellowstone National Park provides the ideal setting to provide students with abundant opportunities to observe and study numerous biological and geological processes. In addition, the students will be provided with cutting-edge portable technology to gather, measure and record scientific observations. The students' E-mate computers provide rd processing, spreadsheet, and drawing capabilities, which are all ideal for recording field data. Yellowstone provides incredible opportunities for observation of various large mammals in their natural environment, and is one of the few natural laboratories in North America where interactions between predators and prey can still be observed, with little or no impact on their natural behavior. Students will use the portable computers to record behavioral observations in the field as they occur. In addition, the E-Mates are equipped with number of probes that can be

used to measure temperature, pH, and dissolved oxygen. These provide data from the numerous thermal features and water bodies in the park. Video and Quick take clips will also be used on the trip to record students' experiences. Upon their return, the students will take their recorded data and complete a scientific summary paper. Students will use video and still shots in addition to their experiences to construct a web page of their trip to be posted on the Internet.

Findings: The only thing collected from the park will be the water data and wildlife observation data that the students will use to prepare a report of their trip. In addition, photography and video will be used to document the student experiences.

Project title: Habitat Use, Diet Quality and Composition of a Pronghorn Population in Yellowstone

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Objective: To develop robust predictive models that describe how pronghorn use winter and spring habitats and predict pronghorn habitat use under varying environmental conditions. A second objective is to evaluate the nutritional content of pronghorn diets from known botanical diet compositions using fecal analyses, and nutrient consumption of herbages determined from published values. A third objective is to evaluate the parameters of habitat use and diet composition and quality of YNP's declining pronghorn population within two frames of reference: in the context of other pronghorn populations, both healthy and of low productivity, in comparable studies; and in the context of findings from studies done on this population of pronghorn between 1967-1970 and 1986-1988. An assessment of the current pronghorn winter range will be investigated regarding changes in management, land use, ownership, and quality and quantity of vegetation communities to provide context for the latter comparison. A fourth objective is to describe seasonal home ranges and migration routes, and to provide basic demographic information.

Findings: 1504 observations were made on collared pronghorn during the period of June 1, 1999 and August 31, 2000. The majority of observations occurred during January to March 2000 when the pronghorn were concentrated on the winter range. Prior to and following these months the pronghorn displayed greater mobility over a larger extent of landscape. More time was required to locate pronghorn during these periods. Five pronghorn were collared in March 2000. Six collared does died during the year 2000. The majority of observations made during the period of November 1999 to March 2000 occurred within YNP, and extended from Devil's Slide to Slide Lake on the Old Gardiner Road. Spring migration occurred during April and May 2000. One collared doe migrated out of the park during the spring to the area around Rock Creek in Tom Miner Basin, and currently is still there. Nineteen collared does migrated from the winter range to points from McMinn Bench on the west to Lamar Valley to the east, Specimen Ridge

on the south to the Yellowstone and Lamar Rivers to the north. Seven collared does remained on the winter range throughout the summer. All collared does except the doe at Rock Creek returned to the winter range by November 2000.

The use of vegetation community-type by collared pronghorn from November, 1999 through July 2000 were quantified. The data were obtained from visual observations of the community-type the collared doe was in at the time of observation. Observations occurred more frequently in grass-dominated communities throughout all months except May 2000, when the majority of relocations occurred in sagebrush communities.

The second field season resumed in November 2000. Data-collection methods employed last season have proven effective and will be used again during the current field season. The research is projected to be completed by December 31, 2001.

Project title: Ungulate Carrion Impact on Plant Community Composition and Nutrient Cycling

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Additional investigator(s): Christopher Wilmers

Objective: To determine whether wolf-killed ungulate carcasses are having an impact on plant community composition and nutrient cycling.

Findings: We determined that the sample size required to get a significant result was unattainable. We initially marked 5 rumen piles which all turned out to be in different plant cover types. Wolf kills occur in approximately 10 different plant cover types, so in order to do this study effectively we estimated that we would need at least 10 samples in each of the 10 cover types, which we did not feel we could achieve.

Project title: Development of an Empirical Model for Predicting the Stream Invertebrate Fauna of the Greater Yellowstone Ecosystem: a pilot study

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Additional investigator(s): Trey Simmons

Objective: The primary objective of this study is to develop an empirical model that accurately predicts the

expected invertebrate fauna in streams of the Greater Yellowstone Ecosystem. Models of this type can be used to assess the biological integrity of streams that may be impacted by anthropogenic activity. As predictive models have generally been applied across relatively large spatial scales, we were interested in assessing how they might perform at a relatively small scale, where latitudinal and elevational differences are minimal. An additional objective was to assess whether detailed temperature data improved the performance of these models.

Findings: We collected benthic macroinvertebrates (both quantitative fixed area and qualitative timed samples), periphyton, physical data, and three months of continuous temperature data from 31 streams and rivers in Yellowstone National Park. Temperature data were collected from late June to late September. Sampling and physical data collection were conducted in August and early September. Invertebrates and periphyton are currently in the process of taxonomic identification; however, preliminary results indicate that the small scale model performs reasonably well, and that performance is improved by the inclusion of detailed temperature data.

Project title: Cougar-Wolf Interactions In Yellowstone National Park: Competition, Demographics, And Spatial Relationships

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Objective: To 1) document the characteristics of the cougar population, including population size, survival, cause-specific mortality, natality, and make comparisons with analogous parameters made prior to wolf restoration (Phase I data); 2) assess the effects of cougars on elk and mule deer populations as influenced by the presence of wolves; 3) assess competition and resource partitioning between cougars and wolves by comparing the species' spatial and temporal habitat use patterns and prey utilization characteristics; 4) quantify spatial and temporal interactions between cougars and wolves; and 5) communicate research findings to state and federal agencies and the general public through annual technical reports, research updates, and presentations.

Findings: Hornocker Wildlife Institute (HWI) personnel captured and radio-collared a total of 36 cougars in and adjacent to areas used by three wolf packs on the Northern Yellowstone Study Area (NYSA), Montana, and Wyoming. A sample of 3 to 10 radio-collared wolves was maintained within each wolf pack by the Yellowstone Wolf Restoration Program. Researchers associated with both HWI and Yellowstone National Park (YNP) conducted aerial and ground monitoring of radio-instrumented animals. To conduct winter cougar sign surveys and provide and estimate of cougar populations size, field crews searched 1589 km of track transect during winter 1998-1999 and 1208 km during winter 1999-2000. A minimum of

21-22 adult and subadult cougars were present on the NYSA during the 1998-2000 winter seasons. Ten resident adults (3 male; 7 female) and 5 kittens in 3 family groups are currently being monitored on the NYSA. Six adult females produced 8 litters of 2-4 kittens, resulting in 21 offspring documented during March 1998-August 2000. Eight cougar deaths were documented. All four of female F107's kittens were killed by the Druid wolf pack in two separate events occurring near an elk killed by F107. Three cougars were killed by other cougars and one cougar kitten was killed by a black bear. Eleven cougars have dispersed to areas adjacent to and beyond the NYSA. One-hundred thirty-six positive and probable cougar kills were documented. Prey included 98 elk, 22 mule deer, one bighorn sheep, one antelope, five coyotes, four porcupines, one red squirrel, and one golden eagle. Seven predation sequences of 26 to 35 consecutive days resulted in a mean predation rate of 7.4 days per ungulate kill for the seven cougars sampled. Twenty-seven percent of cougar-killed ungulate prey were scavenged or usurped by other carnivores. We documented visits to 122 cougar kills by wolves (4.9 percent), grizzly bears (4.9 percent), black bears (9.0 percent), coyotes (14.8 percent), foxes (1.6 percent), and other cougars (0.8 percent). Cougars were displaced from kills by wolves in 5 of 6 documented visits.

Project title: Determining Forage Availability and Habitat Use Patterns for Bison in Hayden Valley of Yellowstone National Park

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Additional investigator(s): Tom Olenicki, Peter Gogan, Robert Garrott

Objective: 1) Describe seasonal bison habitat use patterns and factors that influence these patterns in the Hayden Valley of Yellowstone National Park. 2) Identify interactions between bison and vegetation. 3) Develop a monitoring strategy to track changes in vegetation due to ungulate herbivory. 4) Provide baseline data for models of ungulate-vegetation relationships in the Hayden Valley.

Findings: During the 2000 field season we continued monitoring bison distribution and forage utilization. We obtained ground calibrations to develop forage biomass estimates from multispectral imagery for the third year. We measured utilization via exclosure cages for the last of three years and removed all exclosure material from Yellowstone. GPS technology was used to delineate fine scale foraging patterns of bison. Data collected in this and the previous two field seasons will allow us to make spatially explicit estimates of biomass in individual plant communities, produce spatially explicit temporal estimates of plant phenology, and determine how biomass, phenology, or community species composition interact to drive bison foraging patterns. Brief field visits will be necessary in summer 2001 to refine the vegetation map and complete species composition information on vegetation in the Hayden Valley.

Project title: The Dietary and Foraging Ecology of the Yellowstone River Otter: An Umbrella Species for Aquatic Systems

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Objective: We propose to clarify the ecological role of native vs. non-native fish species on Yellowstone river otters by comparing otter populations on two lake systems in YNP: Yellowstone Lake, where the native cutthroat population is still healthy, and the Lewis-Shoshone Lake complex in which non-native fish, primarily lake trout and brown trout, predominate. Specifically, we are characterizing river otter diets through fecal analysis. Furthermore, we are employing stable isotope analysis to determine the trophic interactions among otters and their prey. The data generated by this research will help assess the consequences of the lake trout invasion on a predator whose existence is firmly linked to aquatic systems and may prove critical to the future management of Yellowstone waters.

Findings: Collection of river otter fecal specimens continued this year. In addition, representative fish and invertebrates were collected from Yellowstone and Lewis Lakes for stable isotope analysis. Hair clipped from mounted river otters was collected for the same purpose. Initial stable isotope analysis has been completed. We are currently analyzing fecal samples in the lab and characterizing otter diet by the frequency of occurrence of various prey items. Preliminary data suggest that there is a significant difference in otters' dietary reliance upon trout between the two lake systems. Initial examination of lake and cutthroat trout otoliths indicates that it is likely possible to distinguish the two species on the basis of otolith morphology.

Project title: '96 Field Course: Forest Ecology and Geology of the Yellowstone Country

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Additional investigator(s): Dr. Martin Knoll

Objective: Primary forest objectives are to 1) identify stands representative of the various forest habitat and cover types described by Despain (1990); 2) establish permanent plots within each stand; 3) develop a database of stand characteristics such as tree species composition, height, age, and understory composition

for each plot; and 4) establish transects to investigate species gradients in relationship to thermal features. The plots will be used to illustrate the concept of habitat typing as applied to Yellowstone forests. Primary geology objectives are to 1) study temperature and pH gradients in Yellowstone Lake and representative hot springs; 2) characterize thermal features representative of different regions of the park; and 3) identify rock types characteristic of the major volcanic episodes in Yellowstone NP. The field course is taught during alternate years.

Findings: No activity was conducted this report year.

Project title: Non-Native Plant Monitoring

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Objective: To complete several non-native monitoring projects initiated in Yellowstone since 1995. That included a re-survey of 60 sites established across the park in 1995 and 1996 that were used to assess native and non-native vegetation. Vegetation analyses were done on quadrants at each of those sites and each of the 60 sites was evaluated twice during the season. Foot surveys to evaluate non-native vegetation were also done along 0.25 mile long strips at each site and drive surveys were done on the intervening 5-mile long road sections between sites too. In addition, U.S. 191 was re-surveyed for non-native plants to compare with the results of a study done several years ago.

Findings: The data set produced during this past season is still undergoing evaluation. A technical report of the work done on U.S. 191 is basically done but requires some verification work/fine tuning before submission. The data for the 0.25 mile long park-wide foot surveys at all 60 sites has been entered into spreadsheets as well as the drive survey information for the 5-mile long study sections. Analysis/writing will continue through the spring/summer until completion with technical report submittal to the appropriate offices. A draft manuscript for the entire project will be prepared in collaboration with Tom Olliff and Craig McClure (NPS).

Project title: Study of the Effects of the 1988 Wildfires on Yellowstone Stream Ecosystems

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Objective: The overall objective of this study is to separate the early from the delayed effects of wildfire on stream ecosystems in Yellowstone National Park. Specific goals include documenting changes in stream habitat and biota each successive year following the 1988 wildfires, thus providing a basis for predicting and evaluating the subsequent long-term changes. Few streams greater than 4th order in size were substantially affected by the fires, and this study focuses on stream of 1st through 4th order. To increase the breadth and precision of the study and to provide more general conclusions, each size class (order) is represented by four or five streams, as well as by at least one reference stream that was not affected by the fires. Since 1993 (except for 1998), the research has been limited to streams in the Cache Creek drainage basin and immediately adjacent reference streams due to financial constraints.

Findings: Although the effects of fire were evident in early years of this study, the streams could be characterized as being largely on a "fast recovery track." However, 1991 and 1994 were marked by runoff events that caused substantial alteration of physical habitat in the streams in burned watersheds, particularly those in moderate to steep gradients. Even greater physical alterations occurred in 1995 (and probably in 1996) and were evident again in 1997. The dramatic changes in 1995-1997 are associated with a general increase in precipitation in those years. Disturbances such as these are reflected in declines in the biotic components of the stream and serve as important "resets" in the recovery process. However, as was evident from examination of one of our reference streams (Amphitheater), some of those differences are more a response to a change in annual weather conditions than to fire per se.

The most dramatic differences in the Yellowstone post-fire streams have been in physical alterations of the stream channel and biological restructuring of communities. Channel morphology is different in burned, large order streams, as bank width is larger than in the large unburned stream. Substrate particle size is different also between comparable-size burned and unburned streams. The smaller Cache sites are receiving more fine sediment from surface erosion than the comparable unburned stream. This pattern is not seen in the larger burned streams perhaps because increased stream discharge flushes the fine sediment downstream. Biological patterns among burned and unburned streams are complex, but differences have emerged in the periphyton communities and in the restructuring and densities of macroinvertebrate communities. Chlorophyll and ash-free dry mass (both measures of primary production) are significantly higher in small burned streams. This increase in primary production is predicted as canopy cover is removed and more available light is converted for use in photosynthesis. Increases in primary production in first and second order burned streams may be responsible for the dramatic shift from mayflies, caddisflies, and stoneflies (EPT taxa) to midges. In the first ten post-fire years increases in Baetis (a mayfly) and midges were seen, as these taxa are more invasive and disturbance-adapted. Macroinvertebrate results from 2000 will aid in determining whether there is a relationship between high chlorophyll a concentrations and midge density at the expense of EPT taxa, as chlorophyll a concentrations were double in 2000 than those in 1999. If this relationship holds we expect to see midge densities the same or higher for the smaller Cache sites than those found in 1999. The percent EPT taxa was consistently 70 to 80 percent of the total taxa in unburned and large burned streams for 1998 and 1999. A large difference was found however, in the percent Baetis which increased nine times that found in 1998 in the large burned streams. Further research will aid in further establishing these mid- to long- term community patterns in burned streams.

Project title: The Effect of Environmental Variability on Grizzly Bear Habitat Use

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Objective: The overall design of this project is to utilize existing data, expertise and newly collected data from advanced technologies to evaluate the impact of anthropomorphic influences on grizzly bear (Ursus arctos horribilis) habitat selection. Initially, this study will have three areas of emphasis: 1) to evaluate potential relationships between habitat use and road density; 2) to evaluate potential relationships between habitat use intensity and types of human activity; and 3) to evaluate potential relationships between habitat selection and land management status.

Findings: During the 2000 field season the Interagency Grizzly Bear Study Team and Wyoming Game and Fish were able to instrument 15 bears for this project. Of the 15 grizzly bears collared, 6 were adult females, 2 were sub-adult females, 5 were adult males and 2 were sub-adult males. The first collar was deployed on May 3, 2000 and the last collar was deployed on September 22, 2000. These collars have a programmable duty cycle that we set to attempt a location collection every 210 minutes. The collars will power down on November 15, 2000 and come back on April 15, 2001. The collars also have a remote release mechanism which will automatically release the collar in the middle of summer 2001. Collars will be collected and data downloaded by the researchers. Also during the 2000 field season we collected the remainder of down collars for the 1999 field season, updated ancillary biophysical data sets and began preliminary data analysis. Next year the researchers plan to use this same collar technology and attempt to deploy the 14 more collars. In addition to the collection information on grizzly bears the researchers will continue preliminary data analysis, test the effect of canopy on location acquisition and update the current grizzly bear habitat coverages and other biophysical data layers with available data.

Project title: Developing Effective Ecological Indicators for Watershed Analysis

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Additional investigator(s): Andrew Marcus, Rick Lawrence, Wayne Minshall

Objective: This study is designed to develop improved indicators and innovative techniques for assisting and monitoring ecological integrity at the watershed level in the western United States. Its specific objectives are to develop practical, scientifically valid indicators that 1) span multiple resource categories; 2) are relatively scale independent; 3) address different levels of biological organization; 4) can be rapidly and cost-effectively monitored by remote sensing; and 5) are sensitive to a broad range of anthropogenic and natural environmental stressors.

Findings: None to report.

Project title: Ecology of Selected Habitats in Yellowstone National Park

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Additional investigator(s): Jeff Schloss

Objective: To 1) quantify the age distribution and density of lodgepole pine in unburned areas and pine recovery in 1988 burned and 1984 blowdown areas; 2) evaluate the influence of thermal runoff on aquatic macroinvertebrates in streams draining geyser basins and compare them to streams lacking thermal runoff that were sampled outside of the park; and 3) observe the adaptations of bacteria, algae, and other life to the diverse hydrothermal features unique to YNP.

Findings: We found that lodgepole pine occurs in burned areas at densities nearly 10 times those in unburned and blowdown areas. Most trees in the burned areas were approximately 11 years old with 3-9 cm main stem diameters. The Firehole River was significantly warmer (26C) than streams at comparable elevations outside the park (e.g., the Tongue River in the Bighorn Mountains [18C]) and harbored some invertebrates (e.g., amphipod crustaceans and gastropod mollusks) that streams without thermal runoff did not. At West Thumb Geyser Basin, as has been previously published, distributions of bacteria, algae, and cyanobacteria were related to water temperature, as determined by visible color of the microbial mats. These results are intended for educational use only and not for scientific discovery; nor are they intended for publication.

Project title: Multi-Trophic Level Responses to the Addition of a Top Carnivore

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Objective: This study examines the ecological changes associated with re-establishment of wolves in Yellowstone National Park in 1995 and 1996. Species representing three important trophic levels—wolves, elk, and woody vegetation—are the focus of the research. The specific areas of interest are: 1) spatial and temporal patterns of abundance of the newly introduced top carnivore (gray wolf), the dominant herbivore (elk), and woody vegetation on YNP's northern range and 2) mechanisms underlying trophic dynamics, especially predation rate of wolves and herbivory use by elk on woody vegetation.

Findings: On March 15 and 16, 2000, 45 cow elk were captured via helicopter netgunning on YNP's northern range. The elk were fitted with mortality-sensing radio collars, and a full range of physiological samples was obtained from each elk, including an incisor for aging by *cementum annuli*. Since capture the elk have been monitored several times per week by ground and/or air to examine habitat associations and temporal/spatial patterns. Beginning in late June, the radiocollared elk were tracked every 7-14 days using aerial telemetry. During the summer, these animals ranged throughout the Quadrant, Buffalo Plateau, Mirror Plateau, Cache Creek, Cold/Mist Creeks, and Heart Lake regions. Fall migration occurred between mid-October and early November, during which time all of the tagged elk returned to the northern range. Monitoring of the study animals will continue through 2001 and preliminary analysis of habitat selection has begun. Final habitat selection models are expected to be available in April 2002.

Four of the 45 elk died in 2000 of the following causes: cougar-kill, wolf-kill, unknown predation, and uncertain cause of death (possible fall). Two of the four elk that died may have been hampered by capture-related injuries. Wolf monitoring occurred on a continual basis with intensified efforts during the two winter study periods of Nov/Dec and March. As of year-end 2000, an estimated 168 wolves in 16 packs inhabited the Yellowstone ecosystem. Of this total, 5 packs, or 72 wolves occupied the northern range. As expected, the northern Yellowstone elk herd is providing most of the prey consumed by Yellowstone wolves. The northern herd population reconstruction effort is underway. Elk mortality data has been obtained from the wolf project database (Doug Smith), the Gardiner late hunts (Tom Lemke), and from winterkill transect surveys carried out by a cooperative team (Peter Gogan, BRD-USGS). A methodology for combining these sources of data to obtain a final minimum number alive (MNA) estimate of the herd is currently being developed.

Project title: Aspen Regeneration in Northern Yellowstone National Park

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Objective: Our objective was to measure aspen regenerative success inside and outside of established wolf pack territories on YNP's northern range. Based on trophic cascades theory, we hypothesized that wolves may displace elk from some areas of the northern range, thus allowing more robust aspen regeneration in areas of higher wolf presence. Using radio telemetry data on wolves and a fixed kernel estimate, we delineated polygons representing high-use winter activity areas of the Leopold, Rose Creek, and Druid wolf packs. These polygons were then overlaid onto a map of northern range aspen stands. Aspen stands were divided into two groups, those within polygons representing a high density of wolf telemetry locations (less than 50 percent fixed kernel estimate) and aspen stands in areas of lower densities of wolf telemetry locations (greater than 75 percent fixed kernel estimate). Permanent 1x20 m belt transects (plots) were established in the aspen stands, marked with both a metal identification tag on a large-stemmed aspen tree and nails in the ground at 3,5,10,and 20 m from the starting point.

Findings: Field data were collected from 112 plots in northern range aspen stands. Differentially corrected GPS readings were obtained from each stand. Aspen overstory density and diameter at breast height (DBH) were recorded. Sucker density, heights, and whether the suckers had been browsed the previous winter were recorded. The number of elk pellet groups was recorded for each plot. The generalized habitat type of each aspen stand was recorded using the categories of mesic upland steppe, xeric upland steppe, and wet meadow/riparian. The aspect, slope, elevation, and recent fire history of each stand were recorded. We have summarized our findings in a manuscript that is currently in review for publication and we plan on collecting new data from our permanent plots during the summer of 2001.

Project title: Causes and Consequences of Alternative Successional Trajectories Following the 1988 Yellowstone Fires

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Additional investigator(s): Monica G. Turner, Gerald A. Tuskan, Dennis H. Knight

Objective: To 1) predict and map the early successional pathways of areas burned in 1988 on the basis of percent serotinous lodgepole pine trees, size of burned patch, and local severity of fire; 2) map percentage of serotinous trees across the landscape; 3) measure aboveground net primary productivity and leaf area index in stands representing different initial pathways of plant succession following the Yellowstone fires of 1988; and 4) re-sample plant cover and density in the permanent plots established in 1990 within nine different patches of 1988 crown fire.

Findings: 1) We obtained 1:30,000 color aerial photos of the entire Park in August 1998. Approximately

10 percent of the area that burned in 1988 now supports very high-density stands of 10-year old lodgepole pine trees (greater than 50,000 stems/ha); 10 percent supports very low-density lodgepole pine (less than 100 stems/ha); and the remaining burned area has stands of intermediate tree density. 2) Initial sampling of percent serenity indicated highest percentages at lower elevations in the west-central portion of Yellowstone NP, and lowest percentages in high-elevation forests in the central and eastern portions of the park. 3) Aboveground net primary productivity (ANPP) and leaf area index (LAI) were measured in 1999 in 88 stands that had burned in 1988. These fundamental measures of ecosystem function varied with sapling density, ranging from 0.9 - 12.6 Mg/ha/yr (ANPP) and from 0.03 - 4.6 m2/m2 (LAI).

Project title: Willow Persistence in Yellowstone National Park: Interactive Effects of Climate, Hydrology and Herbivory

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Objective: To provide some baseline data for developing a research proposal on the effects of population limitation of elk by wolves on willow communities on the northern winter range.

Findings: Study sites that were part of studies conducted by F. J. Singer from 1988-1992 were revisited and we collected data on willow consumption by ungulates and previous year's willow production and growth. This information was incorporated into research proposals recently submitted to the park and National Science Foundation.

Project title: Yellowstone Gray Wolf Restoration Project

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Objective: Restoring wolves *(Canis lupus)* to areas where they were eradicated has been an issue for well over 20 years. Yellowstone National Park, with its plentiful ungulates and large protected ecosystem, has figured prominently in all discussions concerning wolf restoration. For many years it was hoped that

wolves would naturally recolonize the Greater Yellowstone Ecosystem, as they did northwestern Montana around Glacier National Park. However, after in-depth considerations of all aspects related to wolf recovery in the northern Rocky Mountains it was decided to reintroduce wolves to the Yellowstone Ecosystem as part of a program to also return self-sustaining wolf populations to suitable habitat in northwestern Montana and central Idaho. The goal is to have 10 wolf packs (about 100 wolves total) in each of these three areas. When 10 packs have produced wolf pups for three consecutive years in each of the three areas, the gray wolf will be proposed for removal from the list of endangered species and managed as a resident species by the states of Montana, Wyoming, and Idaho within their jurisdiction.

Much work remains after wolves are reintroduced to ensure that the animals form a fully restored and self-sustaining population. The wolves must be closely monitored to respond to any problems that may arise, to determine if and when the goal of a self-sustaining population of wolves has been reached, and to learn about their effects on other ecosystem inhabitants. Accordingly, this plan describes the actions necessary to document establishment of packs, adult wolf survival and mortality, population dispersal and distribution, wolf prey selection and predation rates, and den site location and pup survival.

Findings: At the end of 2000, at least 165 wolves in 16 packs were present in the Greater Yellowstone Area (GYA). Eleven of these packs were considered a breeding pair by the definition established by the U.S. Fish and Wildlife Service (a breeding male and female with two pups that survive to December 31). Eight packs (~126 wolves) reside within YNP, and 8 packs (two in Montana and six in Wyoming) range entirely outside the park (~39-43 wolves). Removal of wolves from the endangered species list requires 30 breeding pairs distributed throughout the three recovery areas (GYA, central Idaho, and northwest Montana) for three successive years. In 2000, there were 25 breeding pairs in the northern Rocky Mountains; therefore 2000 was not a countdown year.

Sixty-nine to 78 pups survived to December 31, 2000. Fifty-five to 60 of these pups were born in YNP. Pup survival was higher in YNP in 2000 (55 of 69, 80 percent) than in 1999 (18 of 40, 45 percent). Parvovirus possibly explained the low survival in 1999. All captured wolves in 1999 and 2000 tested positive for the disease, and mortality occurred at a time (post-weaning) when pups are maximally vulnerable to infection. To positively identify mortality due to parvovirus a dead pup must be collected, and thus far no such carcass has been retrieved.

Fifteen litters were born to eleven breeding pairs. Two packs had more than one litter, the Druid Peak pack had at least three, and the Rose Creek pack had two. Because a breeding pair is only counted if a male and a female successfully raise two pups to December 31, and in both of these packs one male bred more than one female, each pack counts as one breeding pair. Litter size ranged from 4-10 and averaged 6.4 (N = 12).

Project title: Biogeochemical Interactions at Environmental Interfaces (Mercury dynamics in aquatic ecosystems of Yellowstone National Park)

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Objective: The objectives of this study are to understand the dynamics of mercury and methyl-mercury in ecosystems of YNP, with particular emphasis on Nymph Lake and areas in the vicinity of Norris Geyser Basin.

Findings: Nymph Lake and nearby ponds, streams, and wetlands of YNP have the highest known natural concentrations of dissolved total-mercury and methyl-mercury measured in any aquatic ecosystem anywhere. Impacts on biota living in the area are not yet known.

Project title: The Behavioral–Ecological Role of Wolf Howling

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Additional investigator(s): Mary Theberge

Objective: To determine the behavioral and ecological role of wolf howling. Also, to compare the howl characteristics of gray wolves, red wolves, and red-wolf-coyote hybrids.

Findings: Study is in progress. Howls are still being collected, and will be for some time because data collection is opportunistic rather than experimental; park rules preclude our initiation of howling responses.

Project title: Sagebrush Ecology and Ungulate Relationships

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Objective: To determine 1) the current status of the sagebrush-shrub community on the northern Yellowstone mule deer winter range and 2) the importance of the sagebrush community to wintering mule deer and elk.

Findings: Mule deer utilize the several sagebrush habitat types in the boundary line area as key wintering types. They use the four woody sagebrushes and three rabbitbrushes heavily as browse, although they display a decided preference among taxa on winter range.

Project title: Ecology of Thermal Communities

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Objective: The objective of this current phase is to follow the long-term dynamics the organisms in thermal communities in the temperature range from 45 degrees C down to ambient.

Findings: The past year emphasized the extreme fluctuations in dragonfly populations from year to year. The major suspected course of this could be temperature and flow fluctuations in the stream due to variable weather. Temperature data-loggers placed directly in the stream have had minimal success due to battery failure at high temperatures and outright theft! I do have air temperatures throughout the year for almost two years, and will try to compare these to weather records from Old Faithful to see if extrapolation of the latter to Gentian Creek in other years is warranted.

Parkwide studies of the warmwater dragonfly and surveys of thermal communities are continuing. Papers are being prepared on the long-term study of dragonfly populations; the community census; and the dynamics of the alkaline thermal community that develops below 40 degrees C. In addition, I am beginning a small book on my own work and that of my students and post-docs since 1968. The title will reflect our work on the ecology of YNP thermal communities in a variety of locations.

Project title: Mycorrhizal Ecology of Thermal Sites in Yellowstone

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Objective: With this research we propose to 1) assess the distribution of mycorrhizal fungi across environmental gradients at hydrothermal sites; 2) measure the effects of mycorrhizae on plant growth in hydrothermal-influenced soils; 3) determine whether fungi in hydrothermal sites are better adapted to maximize mycorrhizal colonization benefits to host plants than fungi from non-hydrothermal sites; and 4)

increase our understanding of this plant/fungal interactions in extreme environments such as the low pH and low nutrient sites found adjacent to hydrothermal sites in Yellowstone.

Findings: Our first objective of this research was to determine whether mycorrhizae were present. We sampled plant roots from four sites including Hundred Springs Plain in the Norris Basin, Amphitheater Springs, the Firehole River near Ojo Caliente, and Rabbit Creek. We found that mycorrhizae were present at all sites, but in lowest abundance at the Ragged Hills Site adjacent to Hundred Springs Plain. At all other sites, colonization levels ranged from 6 to 54 percent, and were present in soils ranging from 3.7 to 6.5, with soil temperatures in the rhizosphere ranging from 21 to 48 degrees Centigrade. We are interested in continuing this research by investigating whether mycorrhizal fungi found at these sites are specifically adapted to site conditions, including high soil temperatures, low pH, and varying element concentrations.